THE

DESCRIPTION and USE

OF A NEW

Astronomical Instrument,

For taking ALTITUDES of the SUN and STARS at SEA,

WITHOUT an HORIZON;

TOGETHER WITH

An Easy and Sure METHOD of OBSERVING

The *Eclipses* of *Jupiter*'s *Satellites*,

Or any other PHOENOMENON of the like Kind, on *Ship-board*;

In order to determine the DIFFERENCE of MERIDIANS at SEA.

To which are added,

TABLES for computing the *Times* when the *Eclipses* of the *First Satellite* of *Jupiter* happen under the *Meridian* of *London*.

LONDON:

Printed for G. STRAHAN, W. MEADOWS, and J. CLARKE, in *Cornhill*; C. RIVINGTON, W. INNYS and R. MANBY, in *St Paul's Church-Yard*; J. MANN, *Optician*, at the *Archimedes*, and J. SENEX, against *St Dunstan's Church* in *Fleet-street*; C. WARD and R. CHANDLER, between the *Temple-Gates*, and at their Shop in *Scarborough*; J. ROBINSON, next the *One Tun Tavern*, and T. HEATH, *Mathematical Instrument-Maker*, next the *Fountain Tavern* in the *Strand*; R. WILLIAMSON near *Gray's-Inn* Gate; and J. STAGG in *Westminster-Hall*. 1735.

THE

DESCRIPTION and USE

OF A NEW

Astronomical Instrument,

For taking ALTITUDES of the SUN and STARS

at SEA,

WITHOUT an HORIZON;

[illegible]

An Easy and Sure Method of Observing

The Eclipses of Jupiter's Satellites,

Or any other PHÆNOMENON of the like Kind at SEA;

In order to determine the LONGITUDE at SEA.

To which are added,

TABLES for computing the Times when the Eclipses of the First Satellite of Jupiter happen under the Meridian of London.

LONDON:

Printed for [illegible]

TO

The Right Honourable Sir CHARLES WAGER, KNT. *First Lord Commissioner of the Admiralty; Admiral of the White Squadron; and Master of the Trinity-House,* &c.

The Right Honourable ARTHUR ONSLOW, *Esq; Speaker of the Honourable House of Commons; and Treasurer of the Navy,* &c.

Sir JOHN NORRIS, *Admiral of the Red Squadron.*

Sir GEORGE WALTON, *Admiral of the Blue Squadron.*

Sir HANS SLOANE, *Bart. Pr. Col. Med. Med. Reg. and President of the Royal Society.*

EDMUND HALLEY, *L L D. Royal Astronomer of* Greenwich.

RICHARD BRADLEY, *M. A.* Savilian *Professor of the Mathematics in* Oxford.

NICHOLAS SANDERSON, *L L D.* Lucasian *Professor of the Mathematics in* Cambridge.

ROBERT SMITH, *L L D.* Plumian *Professor of the Mathematics in* Cambridge.

The Honourable Sir THOMAS HANMER, *Bart.*

The Honourable WILLIAM CLAYTON, *Esq;*

Commissioners appointed by Act of Parliament, for the Discovery of the Longitude at Sea, and for examining, trying, and judging of all Proposals, Experiments, and Improvements relating to the same.

GENTLEMEN,

WE beg leave, in the most respectful manner, to lay before You, *An easy and sure Method of ascertaining the* Longitude, *or* Difference *of* Meridians *at* Sea, *within a Degree of a Great Circle, or sixty Geographical Miles,* by means of certain *Instruments* contrived for that *Purpose*; the *Description* whereof we think proper to exhibit in this *public manner*, in order

order to disappoint the Intentions of some Persons, who are disposed, on all occasions, to assume to themselves the Credit of other Men's Inventions; as well as to prevent the Trouble and Inconvenience that might arise from such a *Pretence* of their having *hit* on the same *Discovery*.

We are not insensible, that a *Proposal* of *this kind* is attended with many *Difficulties* and *Discouragements*: The various *Idle* Schemes and *Chimerical* Projects that have been offered as *Discoveries* of the *Longitude*, have so much prejudiced Men's Minds against all Propositions of this sort, and brought so much Disgrace on the Projectors, that every *Attempt* to solve this *valuable Problem*, is now ridiculed as the effect of a weak, or a distempered Brain: The Thing itself has been so long the *Reproach of Art*, and every *Essay*, how promising soever, has hitherto proved so *unsuccessful*, that the greatest Part of Mankind look on it as an *Impossibility*; for which Reason, we expect, what we say on this Subject, will be treated, by many Persons, with Ridicule and Contempt.

However, we shall endeavour to remove this Prejudice, by shewing, that the *Discovery of the Longitude at Sea*, is neither *impossible*, nor *impracticable*.

With regard to it's *Possibility*, Mathematicians are well enough satisfied in that Point; more especially, the *Method* we are about to *propose*, and hope to render *practicable*, has long been approved of, and recommended by the best Astronomers, *as true in Theory, tho' very difficult in Practice*; which we could readily make appear, by several Testimonies in the *Philosophical Transactions*, and *elsewhere*; but we shall content ourselves, at this Time, with quoting a Passage or two, from the late Reverend Mr *Flamstead*, and the present Royal Astronomer of *Greenwich*, the Learned Dr *Halley*, who are not more universally, than deservedly, celebrated for their consummate Knowledge and Skill in these Affairs.

Mr *Flamstead*'s Words are these; (*Phil. Trans.* No. 151. p. 302.) " *The Eclipses of* Jupiter's Satellites *have been esteemed, and certainly* " *are a much* better Expedient *for the* Discovery *of the* Longitude, " *than any yet known, by reason that they happen* frequently; *and are* " *easily* observable *with a Telescope of* twelve Foot, *or for need, with* " *one of* Eight.

Dr *Halley*,

Dr *Halley* speaking of the Method that the Royal Academy at *Paris* used, for settling the Geographical Situation of Places in *France*, says, (*Phil. Trans.* No. 214. p. 237.) " *The Method they* " *have used to determine the* Longitude *of their Places, is by the Ob-* " *servations of the* Eclipses *of the* First Satellite *of* Jupiter, *which* " *they find almost* instantaneous, *and with good Telescopes, discernable,* " *almost to the very opposition of* Jupiter *to the Sun*; *and it may be* " *said, that this Account of the* Longitudes *observed, has put it* past " doubt, *that this is the* very best way, *could* portable *Telescopes* " suffice *for the Work: And could the* Satellites *be observed at Sea,* " *a* Ship *at* Sea *might be enabled to find the* Meridian *she is in,* " *by the help of the Tables Monsieur* Cassini *has given us in this* " *Volume, discovering with* great exactness *the said* Eclipses, *beyond* " *what we can yet hope to do by the* Moon, *tho' she seem to afford us* " *the only Means practicable for the Seamen. However, before Sailors* " *can make use of this Art of finding the* Longitude, *it will be re-* " *quisite that the* Coast *of the whole* Ocean *be first* laid down *truly*; " *for which Work this Method by the Eclipses of* Jupiter's Satellites, *is* " *most apposite*; *and it may be hoped, that either a true Geometric* " *Theory of the Moon may be discovered, by the Time the Charts* " *are compleated, or else, that some* Invention *of* Shorter Telescopes " *may* suffice *to shew the* Eclipses *of the* Satellites *at* Sea".

Now, with respect to the *Practicability* of this *Method*, here the *great Difficulty* lies; *hic Labor hoc Opus!* In order, then, to render the same *practicable* at *Sea*, and serviceable to our Purpose, *Two Things* are principally required, *viz.*

First, In whatsoever *Place* the *Ship is*, to be capable of *determining*, there, the *Time* of the *Day*, or *Night*, to a sufficient Degree of Exactness.

Secondly, To be able *to observe* the *Eclipses of the First Satellite* of *Jupiter*, (or any other Phœnomenon of the like kind) at *Sea*, the *precise Time* of whose Appearance can be *known* or *predicted*, at some other certain *Place*, or fixed *Meridian*.

As to the *first* of These, *viz.* The *Way* of finding the true *Time of the Day, or Night*, at the *Place* where the *Ship is*; altho' most of the Writers on this Head, have taken it for granted that the Thing is very easy, yet, we apprehend, it cannot be obtained *sufficiently exact*, by any of the *common Methods* practised at Sea: One

of the beſt, and moſt approved, is that by the *riſing of the Sun*, or *a fixed Star*, proper Allowance being made for Refraction, *&c*. And this needing no Inſtrument, would, no doubt, be very *eaſy*, and come near enough the *Truth*, if this *Appearance* could be *accurately* obſerved, as *often* as need ſhould require: But this we are well aſſured is not to be done, by reaſon, that ſuch *accurate* Obſervations can *rarely* be made, for *want* of a clear, perfect, and diſtinct *Horizon*. Wherefore, that we might obtain this *Requiſite* with greater *Certainty*, and more *Frequency*, we contrived a *New Inſtrument*, whereby we are enabled, with much Facility, to take the *Altitudes* of the Sun and Stars at Sea, *without* an *Horizon*, to leſs than Five Minutes, and conſequently to determine the *Latitude* of the *Place*, and the *Time* of the *Day*, or *Night*, at Sea, ſufficiently *exact* for all the Purpoſes of Navigation; eſpecially, if the *Height* of the Sun, or Star, be taken, to anſwer the *laſt* Intention, when it is at ſuch an *Elevation*, as to have little or no *Refraction*; and is likewiſe *near* the *Prime Vertical*, for then it's Altitude is *changed* moſt ſenſibly, and conſiderably, in a very *ſmall ſpace* of *Time*.

This INSTRUMENT we ſhall now deſcribe; and tho' it may be compoſed of any proper *Materials*, and of any *Radius*, yet, we judge, it will be moſt *convenient* for *Uſe*, at *Sea*, to make it a *Sextant* of *Braſs*, caſt in the *Form* exhibited by the *Scheme*; (See *Fig*. 1.) Let the *Radius* CA, of it's greateſt *Arch* AB, be twelve Inches, (or thereabouts) which Arch is *graduated* only into ſingle *Degrees*: The outermoſt *Edge* thereof muſt be curiouſly divided, or cut down, into two Hundred and forty fine *Teeth*, equal to, and at an exact Diſtance from, each other; of which, there will conſequently be *four* in the ſpace of *one* Degree: On the *Center* of this Arch C, is ſuſpended upon an *Axis* that turns in *Pevet* Holes, a ſtrong *Label*, or *Pendulum* of Braſs, C D E F G, fifteen Inches long, which is *elevated* a little above the *Surface* of the Sextant, by means of a *Roller* fixed to it, which runs on the *leſſer* Arch, *m n*, in order to avoid *Friction*, as much as poſſible, in it's Vibration: The *upper* Part of this Pendulum CD, is made in the *Form* of a flat *Ruler*, of the length of nine Inches; the *lower* Part of it, D E F G, is a *Circle*, ſix Inches in Diameter, about one Third of whoſe Area, or the *Segment* thereof, *x y z*, lying directly over the great Arch of

the

the Sextant, is left *open*, that the Degrees thereon graduated may appear thro' it; and the *Chord* of this Segment *x z*, has it's thickneſs filed away, or ſloped down, to a *Bevil* or *Chamferd* Edge, which is made *circular*, ſo that it may *apply* cloſe to the ſaid graduated Arch A B. The remaining *Part* or *Segment* of this Circle, E G F, is filled up with ſolid Braſs, to give it a ſufficient weight. Each *Quadrant* of the *Rim*, or *Periphery* of this Circle D E F G, is divided and numbered into ſixty *equal Parts*, or *Minutes*, like a Dial-Plate: At the *Center* of this Circle *p* is placed, in a proper manner, a *Pinion* of ſixteen Leaves, exactly proportioned to the Teeth of the great Arch, in which it plays freely, and turns *once* round preciſely, whilſt the Label, or Pendulum, paſſes over the ſpace of *four* Degrees: This Pinion carries round with it an *Index*, or *Hand*, I, fixed upon it's *upper* Part, which, in it's Revolution, *marks*, or *points to*, the *Minutes* engraved on the *Periphery*, or Dial-Plate aforeſaid; the Degrees being *ſhewn*, or *cut*, at the ſame Time, on the Arch of the Sextant, by a *right Line*, (drawn for that Purpoſe upon the Slope, or Chamferd Edge, from the Center of the circular Part of the Label, or Pendulum) whilſt it hangs *perpendicular* to the *Horizon*, which it will do moſt conſtantly and exactly, notwithſtanding the ſmall Friction occaſioned by the Pinion, and the Axis on which it turns; provided the Inſtrument be fixed in a vertical Plane, with it's Arch downwards, in the Time of Obſervation.

From what has been ſaid, it is eaſy to perceive, that an Inſtrument thus formed, ought to be held, when it is made uſe of, as *ſteady* as poſſible, leaſt the Pendulum vibrate ſo much, as to cauſe a great Uncertainty, or Error, in the Angle to be meaſured: And here we muſt acknowledge, a conſiderable *Difficulty* occurred in this Matter; for, if plain Sights, or a Teleſcope in the *ordinary* Way, were fixed on one of the Radii of this Sextant, with it's Object-Glaſs towards the Center, and it's Eye-Glaſs next the Arch, it will be neceſſary to *elevate* the Arch, and conſequently the whole Inſtrument above the Eye, in ſuch a manner, as to put the whole Body of the Obſerver into a moſt irkſome and unſteady Poſture; by reaſon, that the Arms muſt be extended upwards, and the Head reclined backwards, in order to view an Object of any conſiderable Altitude: In ſuch an *uneaſy* Poſition, it is ſcarce poſſible to hold any Inſtrument ſo *ſteady* as is requiſite, eſpecially on

on *Ship-board*, which any one may be readily convinced of that is dispoſed to make the Trial: Wherefore, we found it would be abſolutely neceſſary to *contrive* ſome *other* Method, whereby, an Obſerver at Sea might be enabled to hold this Inſtrument with leſs *Uneaſineſs*, and more *Steadineſs*; and this we effected in the following manner.

Inſtead of a Refracting Teleſcope to be placed on it's Radius, as has been uſual, we deviſed a *New Inſtrument*, which for *Diſtinction* ſake, and upon account of the *ſingular Uſe* we deſign to make of it in Aſtronomical Obſervations, we ſhall take the liberty to call an *Aſtroſcope*. An *Aſtroſcope* is thus formed.

In lieu of an Object-Glaſs, let there be made a *triangular Glaſs-Priſm*, one *Face* whereof is a *Segment*, or *Portion* of the Convex Surface of a *Sphere*, whoſe Radius is nearly one half of the Length of the deſigned Inſtrument; and the two other *Faces* Plane-Quadrilateral Figures, three of whoſe *Sides* are *Rectilinear*, and the fourth *Side*, an *Arch* of a Circle: If the *Subtenſe* of the Arch be conſidered as one Side, inſtead of the *Arch* itſelf, then, one of the ſaid Faces will be a *Square*, and the other (which we ſhall call it's Baſe) a *Parallelogram*, whoſe Length is to it's Breadth, in a ſubduplicate *Ratio* of Two to One. The *Angle* of the Priſm in which theſe Plane Faces *meet*, muſt be *Forty-five* Degrees exactly; and then, if we imagine a Plane to paſs through the Periphery which terminates the ſpherical Face, it will be perpendicular to, or make a *Right Angle* with, the ſquare Face, and be *inclined* to the Baſe, or Parallelogram, in an Angle of *Forty-five* Degrees.

In one End of a braſs Tube we fix a *Convex-Lens*, or *Eye-Glaſs*, of a ſhallow Charge, and a great Breadth; and at the other End, the *Priſm* thus formed, with it's Convex Face turned *towards* the Eye-Glaſs, in ſuch a manner, that the *Axis* of the Tube paſſes through the *middle* of it, at right Angles, and inclined to the *Baſe*, or *Parallelogram* of the Priſm, in an Angle of *forty-five* Degrees; then will the *other* Plane Face, or Square, of neceſſity, lie *parallel* to the ſaid Axis; directly over which, to give a Paſſage to the Rays of Light into this Inſtrument, a circular *Hole*, or *Aperture*, of a proper Magnitude, is cut thro' the Side of the Tube.

Thoſe

Thoſe who are skilled in Optics will readily perceive, that if the Rays of Light which flow from any *one Point* of an Object vaſtly diſtant, be conſidered as *parallel* to each other, at their Incidence upon the outermoſt Face of the Priſm, and paſs through it at *Right Angles*, they will be all *reflected* at it's Baſe, in ſuch a manner, as to proceed in Right Lines *parallel* to the Axis of the Tube, till they arrive at the Convex Face, where they will, at their Emergence, be *refracted*, ſo as to *converge* towards a *Point*, nearly diſtant therefrom, by the Diameter of the Sphere to which the ſaid Convex Surface was ground, and will *there* form a diſtant *Image* of the Object; which *Point* muſt therefore be the common *Focus* of the Priſmatic-Object-Glaſs and the Eye-Glaſs; where two *Hairs* are to be placed at Right Angles to each other, interſecting mutually in the Axis of the Tube.

By an *Aſtroſcope* thus formed, this peculiar Advantage is obtained, that we are not obliged to *elevate* it, or hold it *above* the Head, in a troubleſome Poſition, in order to view any Object by it; for it is evident, from it's Conſtruction, that the whole Tube, in the Time of Obſervation, muſt be *depreſſed* below the Eye, till it's Axis lie in ſuch a Situation, as to be *perpendicular* to a Right Line drawn to it, or imagined to be ſo, from the Object to be obſerved; for then the Image of that Object will be diſtinctly ſeen by an Eye looking upon it through the Eye-Glaſs: And here it is to be noted, that all Objects will appear in this *Aſtroſcope*, *Erect*, as in a Day-Teleſcope, but *inverted* with regard to *Right* and *Left*.

On *each* of the outermoſt *Radii* of our Sextant CA and CB, or parallel thereto, we place an *Aſtroſcope*, with it's Eye-Glaſs towards the *Center*, and the Priſmatic-Object-Glaſs towards the *Arch*: And thus the whole *Inſtrument* will be *finiſhed*, and *adapted* for Obſervation, or taking Altitudes at Sea, or Land, *without* an *Horizon*. We ſhall in the next Place explain the

MANNER of USING it.

Let the *Obſerver*, either ſitting or ſtanding, hold the *Inſtrument* in *both* his Hands, with it's Arch *downwards*, in the ſame *vertical* Plane with the *Object*, and placing one Eye to that *End* of the

Astroscope O, which is next the Center, let him *elevate* and *depress* the whole *Instrument*, till the Object becomes *visible*, or *appears* at the *Intersection* of the Hairs, in the *Focus* of the Astroscope; upon which it is to be kept as *steady* as possible, till the Pendulum has nearly finished it's Vibration, or till it's Motion is almost ceased. In this the *sole* Difficulty lies, which will easily be overcome by a little *Custom* and *Practice*; so that a Person some time *accustomed* to make *Observations* with it, on *Ship-board*, will be able to hold it so *steady*, that the *Vacillation* of the Pendulum will *seldom* cause an *Uncertainty* of more than three or four Minutes, in the Angle to be taken: And if the *Motion* of the Ship should be so *great*, at some times, as to make the Index vibrate *more* than is here mentioned, yet the *Extremes* of that Vibration may be *noted*, and the *mean* Number will be that which is required.

By the *Astroscope*, if it be made (as it should be for this Use) to take in an *Area*, or *Field* of seven or eight Degrees, an Object may be readily found in this manner, and brought to the Intersection of the Hairs in it's Axis; the Pendulum then settling itself *perpendicular* to the *Horizon*, may be stopt there by the Finger, or a Catch for that Purpose; and the *Degrees* and *Minutes* shewn thereby, will give us the *true Altitude* of the Object, *quam proximè*, in case *that Astroscope* was made use of which is fixed on the *Radius* C A, drawn from the *Center* C to A, the *beginning* of the Degrees graduated upon the Arch: But if the *other Astroscope* K L is used, (which will be *necessary* when the Object is elevated more than sixty Degrees above the Horizon) then the *Pendulum* in it's perpendicular Situation, will mark the *Degrees*, and the *Index* will shew the *Minutes* of the Object's *Distance* from the *Zenith*.

DEMONSTRATION.

LET S *represent any Object seen in the manner before described, at the Intersection of the Hairs* f, *in the Focus of the* Astroscope, *by the Eye of an Observer placed at* O; *draw the Right Line* S q, *described by a Ray flowing from the Center of the Object, and passing through the middle of the outermost Face of the Prism, at Right Angles, to the Point* q *in it's Base, where it will be reflected, in such a manner, as to become coincident with the Axis of the* Astroscope, *making*

making the Angle S q f, *a Right one (by the Construction of the Prism already given). Continue the Line* S q *till it meet the* Radius *of the Sextant* C A *in* R, *then will the Angle* S R C *be likewise Right, because* R C *is parallel to* q s *(by hypothesis). Through the Point* R, *draw the Right Line* H D, *perpendicular to the Plumb-line of the Pendulum* C D; *which will therefore be an Horizontal Line, and the Angle* H R S, *by consequence, is the true Altitude of the Object* S. *Now we are to prove, that the Angle* R C D, *whose Measure is the Arch* A p, *cut by the Pendulum or Plumb-line* C D, *produced to* p, *is equal to the aforesaid Angle* H R S, *or the true Altitude of the Object. By the thirty-second Proposition of the first Book of* Euclid, *the outward Angle* H R C, *that is, the Angle* H R S + *the Angle* S R C, *is equal to the two inward and opposite Angles taken together,* viz. R C D + R D C; *but the Angle* S R C *is equal to* R D C, *for they are both Right (by Construction as was shewn above); therefore the Angle* H R S *is also equal to the Angle* R C D (Euclid, Axiom 3.) Q. E. D.

In like manner it may be shewn, that the Angle comprehended between the Radius B C *and the vertical Line of the Pendulum* C D, *will be equal to the Zenith-Distance of any Object, seen or observed by means of the other* Astroscope K L, *which lies parallel to the* Radius C B, *drawn from the Center* C *to the End of the Degrees on the Arch at* B.

There is *another Manner* of *observing* the *Sun*'s *Altitude* by this Sextant, when He *shines* clear, which is thus: Let the *Observer* hold the *Instrument* as before, in the same *vertical Plane* with the *Object*, it's Arch being *downwards*, and the *Face* of it turned *towards* him; then let him *elevate* and *depress* it, till a *Convex Lens* fixed upon one of it's *Radii*, form a bright *Spot*, or *Image* of the Sun, at the *Intersection* of two Lines drawn on a *Plane*, that is placed in it's *Focus*, at *Right Angles*, to the Axis of the *Lens*; and the *Pendulum* hanging *perpendicular* at the same time, to the *Horizon*, will shew the *Degrees* and *Minutes* of the Sun's *Altitude*, or his *Distance* from the *Zenith*, in the same manner as before.

It is scarce needful to mention, that if instead of a *Sextant*, the *Instrument* be made a *Quadrant*, one *Astroscope* placed on *either* of the Radii, will *suffice* to observe Objects at *all* Degrees of Altitude. We may likewise add, that for common *Use* at *Sea*, 'twill be sufficient

cient to *graduate* this *Instrument* to every *five Minutes*, which may be done *without* any *Teeth*, *Pinion*, or *Index*; for the *Bevil*, or *Chamferd Edge* of the Pendulum, which *cuts* or *applies* to the *Degrees* of the great *Arch*, may be *divided* after the manner of *Nonius*, so as to *shew* the Angle to every *five Minutes*: And this Method will render the *Instrument* very *cheap*, as well as extremely *simple*, and sufficiently *accurate*.

Having given the *Description* and *Manner* of *using* this *Instrument*, it may be proper to enumerate some of those *Advantages*, upon account of which, it is *preferable* to any other that has hitherto been *invented* for taking the *Altitudes* of Objects at *Sea*.

The *first* Advantage, and not the *least*, results from the very *Nature* and *Construction* of this *Instrument*, whereby we are *enabled* to find the *Latitude* at *Sea*, much *more frequently* than by any other; a thing of such *extraordinary* Use in Navigation, that it is, in the Opinion of many Persons, as much wanted and desired, for the *Safety* of *Ships* and *Preservation* of *Mens Lives*, as the *Longitude* itself: Now, it is but too well known, by long and sad *Experience*, that the very *best Instruments*, if they *require* an *Horizon*, are often rendered *useless* by the *want* of it, when the *Need* of them is greatest, and the *Danger* most imminent; as for instance, in coming in with the *Land* or *Coast* of this Island, in Voyages from the *East* and *West Indies*, &c. for in our *uncertain* Climate 'tis *rare* to have a clear and perfect Horizon, and that too must be seen when the *Sun* is upon the *Meridian*, otherwise 'tis of no Service for this Purpose; by which means a very able Commander assures us, he has been disappointed of obtaining the Sun's *Meridian-Altitude*, from one Day to another, for several Weeks together, and this in no wise occasioned by tempestuous Weather; for Seamen, as the ingenious Mr *Hadley* observes, (*Phil. Trans.* No. 430. p. 167) " *are much oftner sensible* " *of this* [*Impediment*] *in calm Weather than in rough.*" Now the *Necessity* of seeing the Horizon, is an *Inconvenience* we have intirely *removed*, insomuch, that if the *Place* of the *Sun* in the Heavens is but visible, as He shines through a Cloud, tho' so *faintly* as to give *no Shade*, yet an exact *Observation* may be made, and his true *Altitude* obtained, by means of our *Instrument*: But we have yet a much greater *Benefit* by it; for tho' the *Sun* should *not* be *seen*

* at

at *Noon-Day*, it may, and often does happen, that the Heavens are *clear* and *ſerene* at ſome time of the *Night:* And ſince, at *all Hours*, there will be *one* or *other* of the moſt noted of the *fixed Stars*, upon, or near the *Meridian*, the *Opportunities* of taking their *Altitudes*, and conſequently of finding the *Latitude* at *Sea*, will be as *frequent* as can be deſired.

The *ſecond* Advantage of our *Inſtrument* is, that we are *enabled* to obtain the *Altitudes* of the *Sun* and *Stars* at *Sea*, *more accurately* than by any other; and this is derived from the ſame excellent *Property* of it's *Uſefulneſs without* an *Horizon*. With regard to the *Stars*, we need not ſay how altogether *inſufficient* the Inſtruments hitherto uſed, are for *this* Purpoſe; and in taking *Altitudes* of the *Sun*, with the *common* Quadrants, the *Error* that almoſt conſtantly ariſes from the Indiſtinctneſs, Obſcurity, and Uncertainty of the *ſenſible Horizon*, when looked at as an *Object*, is much *greater* than is generally believed by thoſe that have made no Experiments to aſcertain it: However, that the Error is *conſiderable*, we are fully convinced, not only by the *Reaſon* of the *Thing*, but alſo by the *Experience* of a very skillful and judicious Navigator, Captain *Chriſtopher Middleton*; to whom the Public is indebted for many curious and uſeful Obſervations, made in his Voyages to *Hudſon*'s Bay. This Gentleman (whoſe *Example* it is to be wiſhed *other Commanders* of Ships would follow) has *compared* ſeveral *Altitudes* of the *Sun*, taken on *purpoſe*, with very *accurate* Inſtruments, in *ſtill* Water, both *with*, and *without* an *Horizon*; and from all his *Trials*, he conſtantly found a *Difference* between them, and diſcovered an *Error* to be introduced from the *Uncertainty* of the *Horizon* only, which *frequently* amounted to *thirty* Minutes, or more, and *ſeldom* to ſo *little* as five: This *Imperfection* has no place in our *Inſtrument*, which is not *ſubject* to the leaſt *Error* on this *Account*; and the greateſt that can happen thro' the *Unſteadineſs* of the Pendulum, will ſeldom be ſo much as *five* Minutes, in the Hand of an *Obſerver* who has *accuſtomed* himſelf, for a little time, to the *Uſe* of it on *Ship-board*.

A *Method* of taking *Altitudes* at *Sea* to ſo great a Degree of *Exactneſs*, is of ſuch *Advantage*, not only in finding the *Latitude* of the *Place*, but likewiſe for ſolving many *other Problems*; more particularly, that of obtaining the true *Time* of the *Day* or *Night*,

D which

which has hitherto been so *difficult* to accomplish, with sufficient *Certainty*; that Mr *Hodgson*, in his excellent *System of the Mathematics, Vol.* 1. *p.* 383. says, " *Whoever can contrive any way to take* " *the Height of the Sun, or any fixed Star, at Sea, to one or two* " *Minutes, may fairly be entituled to a Share of the Discovery of the* " Longitude, *and ought to have a proportional Reward.*

With respect to the *Accuracy* of our *Instrument*, we shall, in this Place, take notice of *another* Property in which it *excels*, and that is, the *manner* of it's *Graduation*. It has hitherto been very difficult, in Instruments of so *small* a *Radius* as this, to *graduate* them into Parts *minute* enough for very accurate Observations, without much *Confusion*: This *Defect* we have *remedied*, by a *new Method* of dividing the small Space of a Degree, more exactly, minutely, and distinctly, than can be done by any of the common ways in Use: Hence it is that our Sextant is exceeding *accurate*, tho' the Radius be very *small*; and the *Minutes* are as *visible*, and as easily *distinguished* here, as in other Instruments whose Size is ten times as large.

A *third* Advantage of this Instrument is, that we can obtain the *Altitudes* of the *Sun* and *Stars*, at *Sea*, *more easily* than by any other. Now this *Facility* arises from our having only *one Object* to regard, which we can find most *readily* by our *Astroscope*; whereas, those who make use of an *Horizon*, have this *Inconvenience*, that they must, of necessity, see *two Objects* together, at one and the same time; but *one* of these *Objects*, to wit, the *Horizon*, tho' it be ever so clear and perfect, is frequently *lost* by the *Surge* of the *Sea*, or *intercepted* by the *Rising* of the *Billows* between *It* and the Observer's *Eye*; and all Instruments *whatsoever*, that require an *Horizon*, are unavoidably *subject* to this great *Obstruction*; for it is not, *simply*, the *Motion* or *Unsteadiness* of the Observer's Hand, as some have imagined, which, in this Case, *disturbs* the Observation, so much as the *Interposition* of the *Waves* of the Ocean, or the *Swelling* of the *Sea* before-mentioned, that really and absolutely *deprives* us of the *Sight* of the *Horizon*, for some time, permitting it to *return* only by *Fits*, as it were, and *snatching* it again from our *View*, on a sudden. To these *Interruptions* our *Instrument* is not *liable*, which must certainly *recommend* the Use of it, and render it *acceptable* to such as have experienced how tedious, troublesome,

2 and

and difficult it is, to *adjust* the *Sights*, or *Vanes* of the common Quadrants, for taking Altitudes on Ship-board.

The *fourth*, and *last* Advantage, that we shall at present mention, of this *Instrument*, is it's *Usefulness* at *Land*, as well as at *Sea*: Now many Persons who use the Sea, will think, perhaps, they receive no Benefit by this Property of it, but a little Consideration will convince them of the contrary; for it has already been hinted, of how great Service it would be, to have the *Coast of the whole Ocean truly laid down*; and we may reasonably *hope*, that an *Instrument* so *portable*, and not at all *cumbersome*, so *accurate*, and not subject to *warp*, or *alter* with the Weather, in a word, so *easy*, and even *pleasant* in the manner of it's *Use*, will be sufficient of itself, to *induce* the Commanders of Ships, and other curious Persons, to take the *Meridional Altitudes* of the *Sun* or *Stars*, at all the *Places* and *Ports* where they come; by which means, they might soon furnish us with great *Numbers* of exact, and useful *Observations* for correcting and ascertaining the *Situation* of *Places* in *Maps* and *Sea-Charts*, to the great Improvement of *Geography* and *Navigation*; to which, if they would also be pleased to add the *Observations* of the *Eclipses* of *Jupiter*'s *Satellites*, which they may with great Ease and Pleasure do, by means of the *Telescope* hereafter-mentioned, we might soon expect to see those *Arts* advanced to their highest Perfection.

We now proceed to the *second Thing* proposed, *viz.* to be able to *observe* the *Eclipses* of the *First Satellite* of *Jupiter* (or any other Phœnomenon of the like kind) at *Sea*, the *precise Time* of whose Appearance can be *known* or *predicted*, at some other certain *Place*, or fixed *Meridian*.

To this End, we shall here describe the *manner* in which a *Telescope*, easily *manageable* on Ship-board, and altogether *sufficient* for this Purpose, may be formed.

Let there be made a *Tube*, or hollow *Cylinder* of Brass, A B C D, (*vid. Fig.* 2.) about *four Foot* long, and *four Inches*, or somewhat more, in *Diameter*, dyed as *black* as possible on the Inside. At one End of this Tube, a metalline *Speculum*, E F, spherically *concave*, and *polished* with the utmost *Care*, whose *focal Distance* is forty-eight Inches, or thereabouts, must be fixed, so that it's

Axis

Axis may *coincide* exactly with that of the Cylinder: Near the other End of the Tube, which is open, a brass *Arm*, or *Handle* H G, must descend into the middle of it's Cavity, which may be moved *nearer* to, or *farther* from, the great Speculum, as occasion requires, by means of a *Slider*, to which it is fixed at the Side of the Tube.

To the *End* of this *Arm* is cemented a small *oval Plane*, of polished *metal*, or rather a *Triangular Prism* of Glass, *p q r*, whose *uppermost* Angle *r*, is a *Right one*, and the other two are each exactly *Forty-five* Degrees: The *Faces* of the Prism, which meet in the Right Angle, are exactly *square*; and the *third* Face is a Rectangular *Parallelogram*, whose Breadth is to it's Length, as 1 to the square root of 2. This *Prism* must be placed in such a manner, that a *Ray* reflected from the Concave *Speculum*, may pass thro' the *middle* of the square Face *p r*, at *Right Angles*, but *inclined* to the *Parallelogram* in an Angle of *Forty-five* Degrees, and it's *Distance* from the Concave Surface of the Speculum E F, such, that the *Rays* reflected from the *Concave*, *x m*, *z n*, after their *second* Reflection at the Base of the Prism, may *meet* or *unite* in the Inside of the Tube, at *i*; that is, so as the *Distance* of the *Focus i*, from the reflecting *Surface* of the *Prism*, and of *that* from the Concave *Speculum*, may be equal to the *Focal Distance* of the Concave *Speculum* itself. In the Side of the Tube, an *Aperture* or *Space* is cut open, to give a Passage to the reflected *Rays*, which are conveyed to the Eye through three Convex *Eye-Glasses*, placed in a small brass *Tube*, S T O, at Right Angles to the *Great one*: The *Focal Length* of the Lens next the Eye, is about *one Inch*, and as *broad* as may be: The other two Eye-Glasses are exactly a-like, and the Focal Length of each, about two and a half, or three Inches: The *Telescope* thus formed, represents all Objects *Erect*, and they will appear in it as *bright*, as *distinct*, and as *much magnified*, as in the best *refracting one* of sixteen Foot, charged with a *four-Inch* Eye-Glass; and consequently the *Satellites* of *Jupiter*, will be as plainly and clearly discerned in *one*, as in the *other*. Now we have already shewn, by the *Authorities* we quoted, that if such a *Telescope* could be made *useful* and *manageable* on Ship-board, it would not only *suffice*, but also be the *very best way* to determine the *Longitude*, or *Difference* of *Meridians* at *Sea*; but hitherto *no Method* has been *discovered* of making Telescopes *serviceable* at

Sea,

Sea, in celestial Observations, when they *magnify* in any considerable Degree. The *Cause* of this must be attributed, either to the supposed *Impracticability* of *finding* an Object thereby *readily*, or else to the *Difficulty* of keeping it in *View* within the *Telescope*, when it is found, by reason of the rolling Motion of the Ship.

As to the *first Impediment*, which is indeed the *greatest*, we have contrived a Method, whereby it is intirely removed, *viz.* by placing an *Astroscope*, such as we have before described, at *Right Angles*, to the *Axis* of the great *Telescope*, adjoining to, and of the same Length with, the small *Tube* which contains the three Eye-Glasses: By means of this *Astroscope*, which takes in a *Field* of seven or eight Degrees, any Object may be *found* most *readily*, and brought near to the Intersection of the Hairs, in it's Focus, at which Time the *Eye* may be *removed*, with Ease, to the Eye-Glass of the great *Telescope*, (forasmuch as they are close to one another); and the Object will then be *visible* in that also: Those who have *accustomed* themselves to look with *both Eyes* at once, which it is *easy* to do, may place the *Eye-Piece* of the *Astroscope*, at a *Distance* from the *Eye-Piece* of the *Telescope*, equal to *that* between the two Eyes of the Observer, after the manner that is practised in a *Binocle-Telescope*; so that while he sees the Object in the *Astroscope* with *one* Eye, he may likewise view it in the *Telescope* with the *other* Eye.

Now, as to the *second Difficulty* of *retaining* the Object in *View*, without *losing* the *Sight* of it after it is found, We need only observe, that the *Field* of the Great *Telescope* will be a *whole Degree*, or thereabouts, which is a considerable Space; and also that the *Position* in which this kind of Telescope must of necessity be *held*, in the Time of Observation, will, of itself, *contribute* very much to the *Stability* required; for the open *End* of the great Tube will be very *little above* the Eye, and the remaining *Part* of it will lie *intirely below* it, passing along the right Side, or under the right Arm; which is a *Situation* most *advantageous* for supporting, managing, and directing it, with little Trouble or Uneasiness. To this we may likewise add, that it is not in the least *cumbersome* or *unweildy*, either from it's *Length*, or it's *Weight*, which need not be at most, above *fourteen* Pounds; besides, it is easy to *support* the lower End, in which the great Speculum lies, by means of

a *Suspensory* from some Part of the Body, if need require it, so that the Hands shall feel very little of it's Weight, and be at intire *Liberty* to govern and adjust it.

The Learned Dr *Halley* (in the Appendix to the second Edition of *Street's Caroline Tables*) assures us, " *He had found, it only needed " a little Practice, to be able to manage a five or six Foot Telescope, " capable of shewing the Appulses, or Occultations of the fixed Stars by " the Moon, on Ship-board, in moderate Weather*".

Now 'tis evident, that the *Telescope* we have described, takes in a larger Field, and may be *managed* with much *greater* Ease than a *refracting one* of five or six Foot, or even than one of four Foot; for in ours, there will never be any occasion to *recline* the Head, and *extend* the Arms aloft, as 'tis necessary when we look *upwards* at an Object, with a *refracting Telescope*; which manner of Observing is not only *tiresome*, but likewise creates in the Observer so great an *Unsteadiness*, that he cannot, without much *Difficulty*, direct the *Instrument* so as to *keep* the Object in *View* for the smallest Space of Time.

Upon this Head we shall also cite the Authority of that ingenious Gentleman, Mr *Hadley*, before-mentioned, who tells us, (*Phil. Trans.* No. 430. p. 172.) " *He has been informed, that an " Object may be kept in View without much Difficulty, even in pretty " rough Weather, through a* [refracting] *Telescope, magnifying about " ten times: Now as such Telescopes seldom comprehend an Area of " much more than one Degree in Diameter, or at most one Degree " twenty Minutes, it follows, that the Axis of the Telescope is always " kept within forty Minutes, at most, of the Object, and that is the " greatest Vibration of the Image above and below it*".

Wherefore since our Telescope admits of *as large* a Field, and is *less difficult* to manage than those *refracting ones*, which have been found by Experience to be *serviceable* at *Sea*, we may very well venture to affirm, that a little Practice will render it *easy* for an Observer to *hold* our Telescope on Ship-board, so *steady*, that an Object once *seen* in it, will seldom be *lost*, or *thrown out* of it, by the ordinary Motion of the Ship; or if it should sometimes be so, it may quickly be *recovered* again, by the help of the *Astroscope*.

When this Telescope is not used, the *Object-metal* must be taken out of the Tube, and kept close *shut up* from the Air; and if it happen

happen to *soil* or *tarnish*, it may be *cleared* again easily, by rubbing it with soft Leather, or a Rag, and a little Spirit of Wine.

We have now shewn how the *Eclipses* of the *first Satellite* of *Jupiter*, (or any other Phœnomena of the like kind, such as the Eclipses of the other *Satellites*, the Appulses of the Moon to the fixed Stars, *&c.*) may be *observed* at *Sea*, with great *Certainty*, and much *Facility*; as likewise how the *true Time* of that Observation may be *obtained*, at the *Place* where the *Ship is:* It only remains, that we be able to *know* the Time when the *same* Appearance happens in some other *Place*, or fixed *Meridian*; for Example, at *London*; because, this also being ascertained, the *Difference* of the said Times *converted* into Degrees and Minutes of the Equator, will give the *Distance* of the *Meridians* of those two Places, or discover the *Longitude* at *Sea*. Now the Times when the *Eclipses* of the *first Satellite* of *Jupiter* happen under the *Meridian* of *London*, may be computed exactly by the *Tables* annexed.

We think it proper, before we conclude, to intimate of how great *Use* and *Benefit* a good *Time-Keeper* will likewise be, for ascertaining the *Longitude* of *Places* at *Sea*, in the *Intervals* between the *Observations* of these Eclipses: *Instruments* of that kind are now made in so great *Perfection*, that for the most part, they may be *depended on* for several Days together, without any *considerable* Error. However, since by the *Method* here proposed, we shall be furnished with *frequent* Opportunities of *correcting* and *adjusting* them, as well as of *discovering* how much their *Variation* amounts to, in the Time elapsed between one Observation and another, when they go too fast, or too slow; we shall consequently know their daily *Deviation* or *Error*, and in what manner to make a proper *Allowance* for it in our *Calculations*; by which means they will become as *useful* to us, for this Purpose, as if they had gone most constantly *true*, without any *Change* or *Alteration*; all which is so manifest and obvious, that we need not here enlarge upon it.

This Proposal, *Gentlemen*, of a Method for *Discovery* of the *Longitude* at *Sea*, we submit to your Consideration, as you have been constituted the proper *Judges* of it by the *Legislature*; who have also been pleased to declare, that such a *Discovery* would be of

particular

particular Advantage to the Trade of Great Britain, *and an Honour to this Kingdom.*

We therefore hope, that an *Endeavour* to improve so beneficial and excellent an *Art*, as this of *Navigation*, and advance it to a higher Degree of Perfection, will meet with your *Approbation* and *Encouragement.*

We are,

With the greatest Deference, and Regard,

GENTLEMEN,

Your most Obedient, and

Most Humble Servants.

London, *January the* 20*th*, 1734.

Willm Ward

Caleb Smith

TAB. I. Epochæ Conjunctionum Mediarum Primi Satellitis cum Jove, sub Meridiano Londinensi.

An. Jul. Cur.	Conjunct. med. D.	H.	′	″	Num. A.	Num. B.	An. Jul. Cur.	Conjunct. med. D.	H.	′	″	Num. A.	Num. B.
1729	1	6	0	12	715	554	1745	1	7	55	8	63	205
1730	0	20	11	39	799	468	1746	0	22	6	35	148	119
31	0	10	23	7	883	382	47	0	12	18	3	232	33
32	0	0	34	34	967	296	48	0	2	29	30	316	947
33	0	9	14	38	52	215	49	0	11	9	34	400	866
34	1	17	54	41	136	133	50	0	1	21	1	485	780
1735	1	8	6	9	220	47	1751	1	10	1	5	569	698
36	0	22	17	36	305	961	52	1	0	12	33	653	612
37	1	6	57	40	389	880	53	1	8	52	37	738	531
38	0	21	9	7	473	794	54	0	23	4	4	822	445
39	0	11	20	35	557	708	55	0	13	15	32	906	359
1740	0	1	32	2	642	622	1756	0	3	27	0	990	273
41	0	10	12	6	726	540	57	0	12	7	3	75	191
42	0	0	23	33	810	454	58	0	2	18	30	159	110
43	1	9	3	37	895	373	59	1	10	58	34	243	24
44	0	23	15	4	979	287	60	1	1	10	1	328	938

TAB. II. Revolutiones Primi Satellitis Jovis in Mensibus.

Januarii.				Num.	Num.	*Martii.*				Num.	Num.
D.	H.	′	″	A.	B.	D.	H.	′	″	A.	B.
1	18	28	36	0	5	1	4	12	23	14	155
3	12	57	12	1	9	2	22	40	59	14	159
5	7	25	48	1	14	4	17	9	35	15	164
7	1	54	24	2	18	6	11	38	10	15	168
8	20	23	0	2	23	8	6	6	46	16	173
10	14	51	36	2	27	10	0	35	22	16	177
12	9	20	12	3	32	11	19	3	58	16	182
14	3	48	48	3	37	13	13	32	34	17	186
15	22	17	24	4	41	15	8	1	10	17	190
17	16	46	0	4	46	17	2	29	46	18	195
19	11	14	36	4	51	18	20	58	22	18	199
21	5	43	12	5	55	20	15	36	58	18	204
23	0	11	47	5	60	22	9	55	34	19	208
24	18	40	23	6	64	24	4	24	10	19	213
26	13	8	59	6	69	25	22	52	46	20	217
28	7	37	35	7	73	27	17	21	22	20	221
30	2	6	11	7	78	29	11	49	58	20	225
31	20	34	47	7	82	31	6	18	34	21	230
Februarii.						*Aprilis.*					
0	20	34	47	7	82	0	6	8	34	21	230
2	15	3	23	8	87	2	0	47	10	21	235
4	9	31	59	8	92	3	19	15	46	22	239
6	4	0	35	9	96	5	13	44	22	22	244
7	22	29	11	9	101	7	8	12	58	22	248
9	16	57	47	9	105	9	2	41	34	23	252
11	11	26	23	10	110	10	21	10	10	23	257
13	5	54	59	10	114	12	15	38	46	24	261
15	0	23	35	11	118	14	10	7	22	24	265
16	18	52	11	11	123	16	4	35	58	25	270
18	13	20	47	11	128	17	23	4	33	25	274
20	7	49	23	12	132	19	17	33	00	25	279
22	2	17	59	12	137	21	12	1	45	26	283
23	20	46	35	13	141	23	6	30	21	26	287
25	15	15	11	13	146	25	0	58	57	27	292
27	9	43	47	13	150	26	19	27	33	27	296

TAB. II. Revolutiones Primi Satellitis Jovis in Mensibus.

D.	H.	′	″	Num. A.	Num. B.
Aprilis.					
28	13	56	9	27	300
30	8	24	45	28	304
Maii.					
0	8	24	45	28	304
2	2	53	21	28	309
3	21	21	57	29	313
5	15	50	33	29	317
7	10	19	9	29	322
9	4	47	45	30	326
10	23	16	21	30	330
12	17	44	57	31	335
14	12	13	33	31	339
16	6	42	9	31	343
18	1	10	45	32	348
19	19	39	21	32	352
21	14	7	57	33	356
23	8	36	33	33	361
25	3	5	9	33	365
26	21	33	45	34	369
28	16	2	21	34	373
30	10	30	57	35	378
Junii.					
0	10	30	57	35	378
1	4	59	32	35	382
2	23	28	8	36	386
4	17	56	44	36	391
6	12	25	20	36	395
8	6	53	56	37	399
10	1	22	32	37	403
11	19	51	8	38	408
13	14	19	44	38	412
15	8	48	20	38	416
17	3	16	56	39	420
18	21	45	32	39	425
20	16	14	8	40	429
22	10	42	44	40	433

D.	H.	′	″	Num. A.	Num. B.
Junii.					
24	5	11	20	40	438
25	23	39	56	41	442
27	18	8	32	41	446
29	12	37	8	42	450
Julii.					
1	7	5	44	42	455
3	1	34	20	42	459
4	20	2	56	43	463
6	14	31	32	43	468
8	9	0	8	44	472
10	3	28	44	44	476
11	21	57	20	45	480
13	16	25	55	45	485
15	10	54	31	45	489
17	5	23	7	46	493
18	23	51	43	46	498
20	18	20	19	47	502
22	12	48	55	47	506
24	7	17	31	47	510
26	1	46	7	48	515
27	20	14	43	48	519
28	14	43	19	49	523
31	9	11	55	49	528
Augusti.					
0	9	11	55	49	528
2	3	40	31	49	532
3	22	9	7	50	536
5	16	37	43	50	541
7	11	6	19	51	545
9	5	34	55	51	549
11	0	3	31	51	554
12	18	32	7	52	558
14	13	0	43	52	562
16	7	29	19	53	567
18	1	57	55	53	571
19	20	26	31	54	575

TAB. II. Revolutiones Primi Satellitis Jovis in Mensibus.

D.	H.	′	″	Num. A.	Num. B.
Augusti.					
21	14	55	7	54	580
23	9	23	43	54	584
25	3	52	18	55	588
26	22	20	54	55	593
28	16	49	30	56	597
30	11	18	6	56	602
Septembris.					
1	5	46	42	56	606
3	0	15	18	57	610
4	18	43	54	57	615
6	13	12	30	58	619
8	7	41	6	58	624
10	2	9	42	58	628
11	20	38	18	59	632
13	15	6	54	59	637
15	9	35	30	60	641
17	4	4	6	60	646
18	22	32	42	60	650
20	17	1	18	61	655
22	11	29	54	61	659
24	5	58	30	62	663
26	0	27	6	62	668
27	18	55	42	62	672
29	13	24	18	63	677
Octobris.					
1	7	52	54	63	681
3	2	21	30	64	686
4	20	50	6	64	690
6	15	18	41	65	695
8	9	47	17	65	699
10	4	15	53	65	704
11	22	44	29	66	708
13	17	13	5	66	713
15	11	41	41	67	717
17	6	10	17	67	721
19	0	38	53	67	726
20	19	7	29	68	730
22	13	36	5	68	735
24	8	4	41	69	739
26	2	33	17	69	744
27	21	1	5	69	749
29	15	30	29	70	753

D.	H.	′	″	Num. A.	Num. B.
Octobris.					
31	9	59	5	70	758
Novembris.					
0	9	59	5	70	758
2	4	27	41	71	762
3	22	56	17	71	767
5	17	24	53	71	772
7	11	53	29	72	776
9	6	22	5	72	781
11	0	50	41	73	785
12	19	19	17	73	790
14	13	47	53	74	794
16	8	16	29	74	799
18	2	45	5	74	804
19	21	13	40	75	808
21	15	42	16	75	813
23	10	10	52	76	817
25	4	39	28	76	822
26	23	8	4	76	827
28	17	36	40	77	831
30	12	5	16	77	836
Decembris.					
0	12	5	16	77	836
2	6	33	52	78	840
4	1	2	28	78	845
5	19	31	4	78	849
7	13	59	40	79	854
9	8	28	16	79	859
11	2	56	52	80	863
13	21	25	28	80	868
14	15	54	4	80	873
16	10	22	40	81	877
18	4	51	16	81	882
19	23	19	52	82	886
21	17	48	28	82	891
23	12	17	4	82	897
25	6	45	40	83	900
27	1	14	16	83	905
28	19	42	52	84	909
30	14	11	28	84	914

TAB. III. Æquationes Conjunctionum Primi Satellitis cum Jove.

Num. A.	Æquat. Conjunct. Adde. ′	″	Æq. Num. B.	Num. A.	Æquat. Conjunct. Adde. ′	″	Æq. Num. B.	Num. A.	Æquat. Conjunct. Adde. ′	″	Æq. Num. B.	Num. A.	Æquat. Conjunct. Adde. ′	″	Æq. Num. B.
0	39	8	15	128	12	7	26	256	0	1	31	384	11	52	26
4	38	12	16	132	11	27	26	260	0	0	31	388	12	37	26
8	37	16	16	136	10	47	26	264	0	1	31	392	13	23	25
12	36	21	16	140	19	9	27	268	0	3	31	396	14	11	25
16	35	26	17	144	9	31	27	272	0	7	31	400	14	59	25
20	34	30	17	148	8	45	27	276	0	12	31	404	15	48	24
24	33	35	17	152	8	19	27	280	0	19	31	408	16	38	24
28	32	40	18	156	7	44	28	284	0	28	30	412	17	30	24
32	31	45	18	160	7	10	28	288	0	38	30	416	18	22	23
36	30	50	19	164	6	38	28	292	0	50	30	420	19	15	23
40	29	56	19	168	6	7	28	296	1	3	30	424	20	9	23
44	29	3	19	172	5	37	28	300	1	17	30	428	21	4	22
48	28	10	20	176	5	8	29	304	1	33	30	432	22	59	22
52	27	16	20	180	4	41	29	308	1	50	30	436	22	55	22
56	26	23	20	184	4	15	29	312	2	8	30	440	23	53	21
60	25	30	21	188	3	49	29	316	2	28	30	444	24	51	21
64	24	38	21	192	3	24	29	320	2	51	30	448	25	49	21
68	23	47	21	196	3	1	29	324	3	15	29	452	26	48	20
72	22	56	22	200	2	40	30	328	3	40	29	456	27	48	20
76	22	5	22	204	2	20	30	332	4	6	29	460	28	48	19
80	21	15	22	208	2	1	30	336	4	34	29	464	29	49	19
84	20	26	23	212	1	42	30	340	5	3	29	468	30	50	19
88	19	37	23	216	1	25	30	344	5	34	29	472	31	51	18
92	18	48	23	220	1	10	30	348	6	5	28	476	32	53	18
96	18	0	24	224	0	58	30	352	6	38	28	480	33	55	17
100	17	14	24	228	0	47	30	356	7	13	28	484	34	57	17
104	16	28	24	232	0	36	30	360	7	50	28	488	35	59	17
108	15	42	24	236	0	26	30	364	8	27	27	492	37	1	16
112	14	57	25	240	0	18	30	368	9	6	27	496	38	5	16
116	14	13	25	244	0	12	31	372	9	46	27	500	39	8	15
120	13	30	25	248	0	7	31	376	10	27	27	504	40	11	15
124	12	48	26	252	0	4	31	380	11	9	26	508	41	15	14
128	12	7	26	256	0	1	31	384	11	52	26	512	42	17	14

TAB. III. Primæ Æquationes Conjunctionum Primi Satellitis cum Jove.

Num. A.	Æquat. Conjunct. Adde. ′	″	Æq. Num. B.	Num. A.	Æquat. Conjunct. Adde. ′	″	Æq. Num. B.	Num. A.	Æquat. Conjunct. Adde. ′	″	Æq. Num. B.	Num. A.	Æquat. Conjunct. Adde. ′	″	Æq. Num. B.
512	42	17	14	640	70	26	3	768	77	40	0	896	61	48	6
516	43	19	14	644	71	3	3	772	77	29	0	900	61	2	7
520	44	21	13	648	71	38	3	776	77	18	0	904	60	15	7
524	45	23	13	652	72	11	2	780	77	6	0	908	59	28	7
528	46	25	13	656	72	42	2	784	76	51	1	912	58	39	8
532	47	26	12	660	73	13	2	788	76	34	1	916	57	50	8
536	48	27	12	664	73	42	2	792	76	15	1	920	57	1	8
540	49	28	11	668	74	10	2	796	75	56	1	924	56	11	9
544	50	28	11	672	74	36	1	800	75	36	1	928	55	20	9
548	51	28	11	676	75	1	1	804	75	15	1	932	54	29	9
552	52	27	10	680	75	25	1	808	74	52	1	936	53	38	10
556	53	25	10	684	75	48	1	812	74	27	1	940	52	46	10
560	54	23	9	688	76	8	1	816	74	1	2	944	51	53	10
564	55	21	9	692	76	26	1	820	73	35	2	948	51	0	11
568	56	17	9	696	76	43	0	824	73	8	2	952	50	6	11
572	57	12	8	700	76	59	0	828	72	39	2	956	49	13	11
576	58	7	8	704	77	13	0	832	72	9	2	960	48	20	12
580	59	1	8	708	77	26	0	836	71	38	3	964	47	26	12
584	59	54	7	712	77	38	0	840	71	6	3	968	46	31	12
588	60	46	7	716	77	48	0	844	70	32	3	972	45	36	13
592	61	38	6	720	77	57	0	848	69	57	3	976	44	41	13
596	62	28	6	724	78	4	0	852	69	21	3	980	43	46	13
600	63	17	6	728	78	9	0	856	68	45	4	984	42	50	14
604	64	5	5	732	78	13	0	860	68	7	4	988	41	55	14
608	64	53	5	736	78	15	0	864	67	29	4	992	41	0	14
612	65	39	5	740	78	16	0	868	66	49	4	996	40	4	15
616	66	24	5	744	78	15	0	872	66	9	5	1000	39	8	15
620	67	7	4	748	78	12	0	876	65	28	5	1004	38	12	16
624	67	49	4	752	78	9	0	880	64	46	5	1008	37	16	16
628	68	30	4	756	78	4	0	884	64	3	5	1012	36	21	16
632	69	10	4	760	77	58	0	888	63	19	6	1016	35	26	17
636	69	49	3	764	77	50	0	892	62	34	6	1020	34	30	17
640	70	26	3	768	77	40	0	896	61	48	6	1024	33	35	17

TAB. IV. Secundæ Æquationes Conjunctionum Satellitum cum Jove, sive Generalis Æquatio Luminis. Addendæ.

Num. B.	0		100		200		300		400		500		600		700		800		900	
Æqu.	Æquat.		Æquat.		Æquat.		Æquat.		Æquat.		Æquat.		Æquat.		Æquat.		Æquat.		Æquat.	
	′	″	′	″	′	″	′	″	′	″	′	″	′	″	′	″	′	″	′	″
0	14	0	12	52	9	45	5	30	1	37	0	0	1	37	5	30	9	45	12	52
4	14	0	12	46	9	36	5	20	1	30	0	0	1	44	5	40	9	54	12	58
8	13	59	12	40	9	26	5	9	1	23	0	1	1	52	5	51	10	3	13	2
12	13	59	12	35	9	17	4	59	1	16	0	2	1	59	6	1	10	12	13	7
16	13	58	12	29	9	7	4	48	1	9	0	3	2	7	6	11	10	21	13	11
20	13	57	12	23	8	58	4	38	1	3	0	4	2	15	6	22	10	31	13	16
24	13	56	12	17	8	48	4	28	0	57	0	5	2	24	6	33	10	40	13	20
28	13	54	12	11	8	38	4	18	0	52	0	7	2	32	6	44	10	49	13	25
32	13	53	12	4	8	28	4	8	0	46	0	10	2	41	6	55	10	57	13	29
36	13	51	11	56	8	17	3	58	0	40	0	13	2	50	7	5	11	5	13	33
40	13	49	11	49	8	7	3	48	0	35	0	16	2	59	7	16	11	13	13	36
44	13	47	11	42	7	57	3	38	0	31	0	19	3	9	7	26	11	20	13	38
48	13	44	11	34	7	47	3	29	0	27	0	23	3	19	7	36	11	27	13	41
52	13	41	11	27	7	36	3	19	0	23	0	27	3	29	7	47	11	34	13	44
56	13	38	11	20	7	26	3	9	0	19	0	31	3	38	7	57	11	42	13	47
60	13	36	11	13	7	16	2	59	0	16	0	35	3	48	8	7	11	49	13	49
64	13	33	11	5	7	5	2	50	0	13	0	40	3	58	8	17	11	56	13	51
68	13	29	10	57	6	55	2	41	0	10	0	46	4	8	8	28	12	4	13	58
72	13	25	10	49	6	44	2	32	0	7	0	52	4	18	8	38	12	11	13	54
76	13	20	10	40	6	33	2	24	0	5	0	57	4	28	8	48	12	17	13	56
80	13	16	10	31	6	22	2	15	0	4	1	3	4	38	8	58	12	23	13	57
84	13	21	10	21	6	11	2	7	0	3	1	9	4	48	9	7	12	29	13	58
88	13	7	10	12	6	1	1	59	0	2	1	16	4	59	9	17	12	35	13	59
92	13	2	10	3	5	51	1	52	0	1	1	23	5	9	9	26	12	40	13	59
96	12	58	9	54	5	40	1	44	0	0	1	30	5	20	9	36	12	46	14	0
100	12	52	9	45	5	30	1	37	0	0	1	37	5	30	9	45	12	52	14	0

Tertiæ Æquationes Addendæ			
Num. A.	Æquationes.		Num. A.
	′	″	
0	3	30	1000
20	3	29	980
40	3	28	960
60	3	25	940
80	3	19	920
100	3	12	900
120	3	4	880
140	2	56	860
160	2	46	840
180	2	34	820
200	2	22	800
220	2	10	780
240	1	57	760
260	1	44	740
280	1	30	720
300	1	17	700
320	1	5	680
340	0	53	660
360	0	41	640
380	0	31	620
400	0	22	600
420	0	14	580
440	0	8	560
460	0	4	540
480	0	2	520
500	0	0	500

TAB. V.

Semidurationes Eclipsium Primi Satellitis Jovis.

Num. A.	Semidurationes.			Nu. A.	Semidurationes.			Nu. A.	Semidurationes.			Nu. A.	Semidurationes.		
	h.	′	″		h.	′	″		h.	′	″		h.	′	″
0	1	5	9	250	1	7	0	500	1	5	9	750	1	7	46
10	1	4	56	260	1	7	15	510	1	4	53	760	1	7	57
20	1	4	44	270	1	7	31	520	1	4	39	770	1	8	7
30	1	4	33	280	1	7	45	530	1	4	26	780	1	8	15
40	1	4	23	290	1	7	57	540	1	4	15	790	1	8	22
50	1	4	13	300	1	8	7	550	1	4	7	800	1	8	26
60	1	4	7	310	1	8	15	560	1	4	3	810	1	8	28
70	1	4	4	320	1	8	22	570	1	4	1	820	1	8	30
80	1	4	2	330	1	8	27	580	1	4	0	830	1	8	28
90	1	4	0	340	1	8	28	590	1	4	3	840	1	8	26
100	1	4	2	350	1	8	29	600	1	4	7	850	1	8	22
110	1	4	3	360	1	8	27	610	1	4	13	860	1	8	16
120	1	4	6	370	1	8	24	620	1	4	23	870	1	8	8
130	1	4	12	380	1	8	17	630	1	4	35	880	1	8	0
140	1	4	21	390	1	8	9	640	1	4	49	890	1	7	50
150	1	4	31	400	1	7	58	650	1	5	4	900	1	7	37
160	1	4	42	410	1	7	46	660	1	5	19	910	1	7	22
170	1	4	55	420	1	7	31	670	1	5	36	920	1	7	8
180	1	5	9	430	1	7	14	680	1	5	54	930	1	6	55
190	1	5	23	440	1	6	58	690	1	6	10	940	1	6	40
200	1	5	39	450	1	6	40	700	1	6	28	950	1	6	23
210	1	5	55	460	1	6	20	710	1	6	46	960	1	6	8
220	1	6	11	470	1	6	2	720	1	7	2	970	1	5	54
230	1	6	26	480	1	5	45	730	1	7	17	980	1	5	37
240	1	6	43	490	1	5	26	740	1	7	33	990	1	5	22
250	1	7	0	500	1	5	9	750	1	7	46	1000	1	5	9

The Use of the foregoing TABLES; *or* Precepts *for computing, by them, the* Times *when the* Immersions *and* Emersions *of* Jupiter's First Satellite, *happen under the* Meridian *of* London.

1. IN the *first Table*, intituled, *Epochæ Conjunctionum Mediarum*, &c. look for the Year proposed, and write out the Epocha of the mean Conjunction, or the Day, Hour, Minute, and Second thereof, together with it's corresponding Numbers, A, and B.

2. In the *second Table*, intituled, *Revolutiones Primi Satellitis Jovis in Mensibus*, seek the Month in Question, and write out the Day, Hour, Minute, and Second, next less than the Time, on which the Eclipse sought, has already, or will hereafter happen; together with the Numbers A and B, annexed thereto.

3. Add the Numbers A together; and likewise the several Times collected from the Tables *(by the first and second Precept)* and the Sum of these will be the mean Time of the middle of the Eclipse required.

4. Enter the *third Table*, intituled, *Primæ Æquationes Conjunctionum*, &c. with the Sum of the Numbers A, *(obtained by the third Precept)* rejecting the Thousands, and take out the first Equation of the Conjunctions answering thereto; and also the Equation of the Number B.

5. Add together all the several Numbers B, thus equated, (rejecting the Thousands) and write out the second Equation of the Conjunctions, answering to their Sum, from the *fourth* Table, intituled, *Secundæ Æquationes Conjunctionum*, &c. *sive Generalis Æquatio Luminis*.

6. Enter the *fifth*, or *last Table*, intituled, *Tertiæ Æquationes & Semidurationes Eclipsium*, &c. with the former Sum of the Numbers A, *(obtained by the third Precept)* and write out the third Equation corresponding thereto; and likewise the Semi-Duration of the Eclipse, which is to be set down a-part.

7. To the mean Time of the middle of the Eclipse *(obtained by the third Precept)* add all the three Equations *(found by the fourth, fifth, and sixth Precepts)* and that Sum will discover the exact Time of the middle of the Eclipse.

8. If the Sum of the Numbers B, *(Precept the fifth)* is less than five Hundred, subtract the Semi-Duration of the Eclipse, from the Time before found *(by the seventh Direction)* and the

Remainder is the exact Time of the Immersion required: But if the Sum of the Numbers B, is greater than five Hundred, add the same to the former Time, and it will give the exact Time of the Emersion sought.

9. The Time obtained in this manner, is equal Time, which may be reduced to the apparent, or true, by the Tables of Equation of Time; that are every where to be met with.

Note, that in the Bissextile Year, after *February*, one Day must be subtracted from the Day of the Month.

We shall illustrate these Precepts by an Example or two, which will render them very plain and easy.

EXAMPLE I.

At Pekin *in* China, *an* Immersion *of the* First Satellite *of* Jupiter, *was* observed *the 6th of* January, $11^{h}\ 22'\ 30''$ *p. m. (O S) by* Ign. Kogler. (Phil. Transf. No. 420. p. 182.) *The* Time *when the same Eclipse happened under the Meridian of* London, *is required; and also the* Difference *of the* Meridians *of those* Places.

	Y	D	H	′	″	No. A.	No. B.
Epocha of the Conjunctions, (per Tab. 1.)	1730. —	0	20	11	39	799	468
Revolutions of the 1st Satellite, *(per Tab. 2.)*	January.	5	7	25	48	1	14
							1 BEq.
Mean Time *of the* Middle *of the* Eclipse	—	6	3	37	27	800	
1st Equation (per Tab. 3.)	— —		1	15	36		483
2d Equation (per Tab. 4.)	— —			0	3		
3d Equation (per Tab. 5.)	— —			2	22		
Exact Time *of the* Middle *of the* Eclipse, *(Eq. Time)*		6	4	55	28		
Semi-Duration Substract	—		1	8	26	Semi-duration.	
						h ′ ″	
Exact Time *of the* Immersion, *(Eq. Time)*	—	6	3	47	02	1 8 26	
Equation of Time, Substract	—			10	45		
True Time *of the* Immersion *at* London	—	6	3	36	17		
True Time *of the* Immersion *at* Pekin *(supra)*		6	11	22	30		
Horary Difference *of* Meridians	—		7	46	13		

which, converted into Degrees of the Equator, gives 116 *Deg.* 13 *Min. the* Distance *of the* Meridian *of* Pekin *from* that *of* London: *Wherefore, since the Time at* London *was* less *than at* Pekin, *the* Longitude *of* Pekin, *(according to this Observation) is* 116 *Deg.* 13 *Min.* East *from* London.

EXAM-

EXAMPLE II.

At Pekin *in* China, *an* Emersion *of the* First Satellite *of* Jupiter, *was* observed *the* 3*d of* May $9^{h}\ 28'\ 45''$ *p.m.* (O S) *by* Ign. Kogler, (Phil. Trans. No. 420. p. 182.) *The* Time *when the same Eclipse happened under the Meridian of* London, *is required*; *and also the* Difference *of the* Meridians *of those Places.*

	Y	D	H	'	"	No. A.	No. B.
Epocha of the Conjunctions (per Tab. 1.)	1730 —	0	20	11	39	799	468
Revolutions of the 1*st* Satellite *(per Tab.* 2.)	May —	2	2	53	21	28	309
							2 BEq.
Mean Time *of the* Middle *of the* Eclipse —		2	23	05	00	827	—
1*st Equation (per Tab.* 3.) —			1	12	46		779
2*d Equation (per Tab.* 4.) —				8	56		
3*d Equation (per Tab.* 5.) — —				2	38		
Exact *(Equal)* Time *of the* Middle *of the* Eclipse -		3	00	29	20		
Semi-duration add — —			1	8	29	*Semi-duration.*	
						h ' "	
Exact *(Equal)* Time *of the* Emersion —		3	1	37	49	1 8 29	
Equation of Time add —				4	4		
True Time *of the* Immersion *at* London —		3	1	41	53		
True Time *of the* Immersion *at* Pekin *(supra)* —		3	9	28	45		
Horary Difference *of* Meridians —			7	46	52		

which, converted into Degrees of the Equator, gives 116 *Deg.* 23 *Min. the* Difference *of the* Meridians *of* Pekin *and* London: *Wherefore, since the Time at* London *was less than at* Pekin, *the* Longitude *of* Pekin, (*according to this Observation*) *is* 116 *Deg.* 23 *Min.* East *from* London.

F I N I S.

ADVERTISEMENT.

THE ASTROSCOPE *and* TELESCOPE *herein described, are made in the greatest Perfection, by Mr* JAMES MANN, Spectacle-Maker, *at the* Archimedes and two Pair of Golden Spectacles, *near the* Castle-Tavern *in* Fleet-street, London; *who makes and sells, by Wholesale and Retale, all sorts of Prospective-Glasses, Refracting and Reflecting Telescopes, Microscopes, Prisms, Reading-Glasses, Spectacles,* &c.

The SEXTANT, *or* ASTRONOMICAL INSTRUMENT, *herein mentioned, for taking Altitudes of the Sun and Stars, at* Sea, WITHOUT *an* HORIZON, *may be seen at the* Dog-Tavern, *or* Union Coffee-House, *in* Thames-street, *near* Billingsgate; *and is made with the utmost Accuracy, by Mr* THOMAS HEATH, *at the* Hercules, *next door to the* Fountain-Tavern *in the* Strand, London; *who makes and sells, by Wholesale and Retale, all sorts of Mathematical Instruments, for Land and Sea, curiously and exactly finished in Silver, Brass, Ivory, Wood,* &c.

BOOKS Printed for G. STRAHAN, at the *Golden Ball*, over-against the *Royal Exchange*, *Cornhill.*

INtroductio ad Veram Astronomiam, seu Lectiones Astronomicæ, Habitæ in Schola Astronomica Academiæ Oxoniensis. Authore Johanne Keill, *M D.* Astronomiæ Professore Savilliano, *R S S.* Editio Secunda multo Auctior & Emendatior.

Methodus Differentialis; sive Tractatus de Summatione & Interpolatione Serierum Infinitarum. Auctore Jacobo Stirling, *R S S.*

Tentamina Medico-Physica, ad quasdam quæstiones, quæ Oeconomiam Animalem spectant, accommodata. Quibus accessit Medicinæ Statica Britannica. Authore Jacobo Keill, *M D.*